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DIVERSITY RECEPTION SLOTTED FLAT-PLATE ANTENNA

The present invention relates to a planar antenna with diversity of radiation. It relates more particularly to an antenna that can be used in the field of wireless transmissions, particularly within the framework of transmissions in a closed or semi-enclosed environment such as domestic surroundings, gymnasiums, television studios, theatres or similar rooms.

In the known high-speed wireless transmission systems, the signals transmitted by the transmitter reach the receiver by following a plurality of paths resulting from the many reflections of the signal on the walls, furniture or similar elements. When combined at the level of the receiver, the phase differences between the different rays having taken paths of different lengths gives rise to an interference figure that can cause fading or a significant degradation in the signal.

Now, the location of the fading changes over time according to the modifications in the environment such as the presence of new objects or the movement of people. The fading due to multipaths can lead to significant degradations both at the level of the quality of the signal received and at the level of the system performances. To overcome these fading phenomena, the technique most often used is a technique that implements spatial diversity.

This technique consists, among other things, of using a pair of antennas with wide spatial coverage connected by feed-lines to a switch. However, the use of this type of diversity requires a minimum spacing between the radiating elements to ensure that there is sufficient decorrelation of the channel response viewed from each radiating element. An inherent disadvantage to its implementation is the distance between the radiating elements that present a cost, particularly in terms of size and substrate.

Other solutions have been proposed to overcome this problem. Some of these solutions use diversity of radiation as described for example in the French patent A-2 828 584 in the name of the applicant.

as filed

The present invention proposes a new planar type antenna with diversity of radiation.

Hence, the present invention relates to a planar antenna realised on a substrate comprising a slot of closed shape dimensioned to operate at a given frequency in a short-circuit plane of at least one feed-line. In this antenna, the perimeter of the slot is designed such that $p = k\lambda s$ where k is a integer greater than 1 and λs the guided wavelength in the slot. Moreover, it comprises at least a first feed-line placed in an open circuit zone of the slot and a second feed-line placed at a distance $d = (2n+1)\ \lambda s/4$ from the first line, where n is an integer greater than or equal to zero.

According to a first embodiment, each feed-line terminates in an open circuit and is coupled to the slot according to a line/slot coupling such that the length of the line after the transition equals $(2k'+1)\lambda m/4$ where λm is the guided wavelength under the line and k' a positive or null integer. The line/slot coupling can also be realised in such a manner that the microstrip line terminates in a short-circuit located at $2k''\lambda m/4$ where λm is the guided wavelength under the line and k'' is a positive or null integer.

According to a second embodiment, each feed-line is coupled magnetically with the slot according to a tangential line/slot transition.

Moreover, the shape of the slot can be annular, square, rectangular, polygonal, or in the form of a clover leaf. If the slot is of a rectangular shape, the feed-lines can be equidistant from an axis of symmetry of the slot or one of the feed-lines is positioned according to an axis of symmetry of the slot.

Other characteristics and advantages of the present invention will emerge upon reading the following description of different embodiments, this description being made with reference to the drawings attached in the appendix, in which:

Figure 1 is a diagrammatic top plan view of a first embodiment.

Figure 2 is a curve showing the antenna parameters of figure 1.

Figures 3a and 3b respectively show the radiation patterns of the antenna of figure 1 when is its fed respectively by the access 1 or by the access 2.

Figure 4 is a cross-section of the radiation patterns of the figures 3.

Figure 5 shows the isolation curves S12 for a second access at 45° or 135°.

Figure 6 is a diagrammatic top plan view of another embodiment of an antenna in accordance with the invention.

Figures 7a and 7b respectively show the radiation patterns of the antenna of figure 6 when it is fed respectively by the access 1 or by the access 2.

Figures 8a and 8b representing the parameters S of the antenna of figure 6 for different values of the quarter wavelength.

Figure 9 is a diagrammatic top plan view of another embodiment of an antenna in accordance with the invention.

Figure 10 shows the parameters S of the antenna of figure 9.

Figures 11a and 11b respectively show the radiation patterns of the antenna of figure 9.

Figure 12 is a diagrammatic plan view of diverse shapes for the antenna.

Figure 13 is a diagrammatic plan view of yet another embodiment of the invention.

Figure 14 is a diagrammatic view of an antenna in accordance with the invention integrating a Tx access and two Rx accesses.

To simplify the description, the same elements have the same references as the figures.

Figures 1 to 5 relate to a first embodiment of the invention. As shown in figure 1, the planar antenna is constituted by an annular slot 1 realised on a substrate 2 by engraving on a ground plane that is not shown. The antenna operates on a higher order mode, more particularly on its first higher order mode. Therefore, the perimeter of the annular slot 1 is equal to

$2\lambda s$, where λs is the guided wavelength in the slot. Generally, the perimeter of the slot is such that $p = k\lambda s$ where $k > 1$.

As shown in figure 1, the excitation of the slot is achieved by using a feed-line 3 realised in microstrip technology. The line 3 crosses the slot so as to obtain a coupling between the microstrip line and the slot according to the method described by Knorr. Thus, the length Lm of the line 3 equals approximately $(2k'+1)\,\lambda m/4$ where λm is the guided wavelength under the line and k' a positive or null integer, the most frequently $Lm = \lambda m/4$. Moreover, as shown in figure 1, the distribution of the fields in the annular slot has maximum field zones (OC zones for Open Circuit) and minimum field zone (SC zones for Short-Circuit). The feed-line 3 crosses the annular slot 1 in an open circuit zone. Owing to the positioning of the feed-line and the perimeter of the annular slot, the distance between two OC zones or two SC zones is $\lambda s/2$. This distribution of fields in the slot determines the radiation pattern of the antenna. The radiation is in the plane of the substrate, in contrast to the annular slot operating in its fundamental mode, for which the radiation is perpendicular to the substrate. According to one variant, the feed-line 3 terminates in a short-circuit. In this case, the length of the line (Lm) is chosen such that $Lm = k''\lambda m/4$, where k" is a positive or null integer.

In accordance with the invention, a second feed-line 4 realised in microstrip technology and crossing the slot according to the Knorr method is positioned at the level of a SC zone. The length of the feed-line 4 is determined according to the rules mentioned above. Thus, when the access is realised by line 4, a second radiation pattern is obtained that is complementary to the first one. More specifically, the second line is located at +/-45° or +/-135° with respect to the first line, namely at a distance d such that $d = (2n+1)\,\lambda s/4$. This relative position of the two accesses enables a good level of isolation to be obtained.

The dimensions taken for an embodiment compliant with that of figure 1, which was simulated by using the IE3D software of the Zeland company, will be given below. On a Rogers RO4003 substrate presenting a

εr = 3.38, a loss tangent TanΔ = 0.0022 and a height H = 0.81 mm, was realised an antenna such as represented in figure 1. This antenna is constituted by an annular slot presenting an internal diameter Rint = 13.4 mm and an external diameter Rext = 13.8 mm, namely an average diameter Ravg = 13.6 mm. The width of the slot equals Ws = 0.4 mm. The feed-lines are realised using microstrip technology and have a width Wm = 0.3 mm and length Lm = λm/4 such that Lm = Lm' = 8.25 mm.

As shown in figure 1, the distance between the two accesses 1 and 2, when the slot is a circle, corresponds to 1/8th of the perimeter namely 2πraverage/8 = 10.68 mm. This corresponds to a quarter guided wavelength in the slot (λs/4 = 10.66 mm). At the level of accesses ❶ and ❷ for feeding the lines 3, 4, the impedance is 50 ohms. Figure 2 shows the results obtained concerning the isolation S and matching parameters according to the frequency. It is seen in this case that an isolation of around –20dB is obtained.

Moreover, according to the radiation patterns shown in figures 3a and 3b, four lobes oriented according to directions Ox and Oy are distinguished when the access ❶ is used, as shown in figure 3a whereas when access ❷ is used, the lobes are turned by 45°, as shown in figure 3b. Therefore two complementary radiation patterns are obtained, as shown in figure 4 which shows a cross-section in the plane ϑ = 95° of the radiation patterns shown in figures 3a and 3b.

It should also be noted that with this antenna, the radiation is produced in the plane of the substrate, which enables a horizontal coverage to be obtained for a single stage use, for example.

In accordance with the present invention, the second access, namely the microstrip line 4, can be placed at +/-135° (+/-3λs/4) in relation to the first access, namely the feed-line 3. This enables an improvement of approximately 8dB in the isolation level to be obtained, as shown in figure 5 between the two curves S12 (135° access) and S12 (45° access).

A description will now be given, with reference to figures 6 to 8, of another embodiment of an antenna in accordance with the present invention.

In this case, as shown in figure 6, instead of having a circular shaped slot, a slot 10 of rectangular shape is used. The length of the rectangular shape is such that $p = 2\lambda s = 2(W+L)$ where W corresponds to the width of the rectangle and L to the length of the rectangle. More generally, $p = k\lambda s = 2(W+L)$. In this case, as shown in figure 6, the rectangular shaped slot is fed by two feed-lines 11 and 12 realised using microstrip technology. The feed is produced by line/slot coupling according to the method described by Knorr and mentioned above.

In accordance with the invention, the first feed-line 12 is positioned on an axis of symmetry of the structure, namely the axis x, x' whereas the second feed-line, namely line 11 is positioned at a distance $d = (2n+1)\ \lambda s/4$ where n is an integer greater than or equal to zero. In these conditions, access to the feed-line 11 is not obtained by symmetry of the axis realised by the feed-line 12. This asymmetry is located at the level of the impedance matching of the ports. Indeed, an imbalance occurs between the S11 and S22 impedance matching in terms of central frequency and impedance matching band.

In this case, the frequency can be recentered by modifying the quarter wave (Lm'Wm') located between the access port and the line-slot transition as will be explained below.

With a rectangular shape as shown in figure 6, the radiation patterns as shown in figures 7a for feeding by line 12 or 7b for feeding by line 11 are obtained. It is observed that the patterns obtained are modified with respect to the pattern of a circular slot but remain complementary. Hence, through the shape of the slot, it is possible to control the radiation patterns.

The following describes a practical embodiment of an antenna as shown in figure 6. This antenna was simulated by using the IE3D software with the following dimensions in millimetres:

L = 32.92 mm

W = 11.24 mm

D = 18.84 mm

Ws = 0.4 mm

Lm = Lm' = 8.85 mm

Wm = Wm' = 0.15 mm.

As shown in the curves of figure 8a, it is seen that in this case, there are two peaks of impedance matching that are not centred on the same frequency. To obtain a centring of the two peaks, the quarter wavelength of the access 1 was modified such that Lm' = 7.85 mm and Wm' = 0.75 mm. In this case, the parameters S of figure 8b were obtained. The quarter wave of the access corresponding to line 11 not having been modified, the two impedance matching peaks are centred on the same frequency.

A third embodiment will be described below with reference to figures 9 to 11. In this case, the antenna constituted by a slot with a closed shape is realised by a rectangular slot 20 with two accesses formed by the feed-lines 21, 22 that are symmetrical in relation to the line x x'. With this symmetrical access structure, a balanced matching is obtained if the perimeter p of the rectangular slot is selected such that $p = 2\lambda s = 2(W+L)$ where W is the rectangle width and L its length, λs being the guided wavelength in the slot. As mentioned above, p can also be chosen such that $p = k\lambda s$. Moreover, the distance between the access of the line 22 and the access of the line 21 is such that $d = (2n+1)\ \lambda s/4$ where n is an integer greater than or equal to zero and the accesses formed by the lines 21 and 22 are equidistant from an axis of symmetry XX' of the rectangular slot.

In this case, as shown in figure 10 which gives the parameters S of the rectangular slot with symmetrical accesses, the two impedance matching peaks are exactly superimposed but the level of isolation is higher for the antenna constituted by a rectangular slot with an asymmetrical access as shown in figure 6.

The antenna structure of figure 9 gives different radiation patterns according to the access used, as shown by the pattern of figure 11a and 11b.

The embodiments shown above are related to planar antennas constituted by a slot of a closed, annular or rectangular shape. However, as shown in figure 12, other closed shapes can be used for the slot antenna, particularly an orthogonal shape 30, a square 40, a clover leaf shape 50. One of the operating conditions is that the perimeter of the slot is an integer multiple k greater than or equal to 2 of the guided wavelength in the slot $p = k\lambda s$ and that the distance d between the accesses is such that $d = 2(n+1)\lambda s/4$ where n is an integer greater than or equal to zero.

In this case, a higher order mode of the slot is used, which enables complementary radiation patterns to be obtained. Particularly, the structures proposed radiate in the plane of the substrate, which is not the case with a slot antenna operating in its fundamental mode.

According to a variant of the present invention as shown in figure 13, the antenna-slot 60 that, in this embodiment, is constituted by a ring can be fed tangentially, as shown by the feed-lines 61, 62. In this case, the same design rules are used. The advantage of a tangential feed is to have feed-lines outside of the slot and to increase the bandwidth.

In accordance with the present invention and as shown in figure 14, if the closed shape slot antenna is constituted particularly by a rectangle or a square, it is possible to realise a structure enabling a reception/transmission operation with a good isolation and a diversity of the order of 2 for reception. The Rx/Tx isolation obtained is that given in figure 8 in the case of a rectangular slot. The radiation pattern of the antenna fed by the access Tx corresponds to that of figure 7a and that of the antenna fed by access Rx1 corresponds to the pattern of figure 7b. Likewise the pattern of the antenna fed by the access Rx2 is symmetrical with respect to the axis Ox of the pattern represented in figure 7b. The distance between the two accesses Rx is $\lambda s/2$ or more generally $k'''\lambda s/2$ where k''' is an integer greater than 0. Hence, the isolation is not intrinsically good between these two accesses. A switching device such as the SPDT circuit will be used at the level of the Rx access.

The use of this type of structure thus enables a good level of isolation to be obtained and a diversity of order 2 for reception with very low overall dimensions when an integrated switching device is used.

It is evident to those in the profession that modifications can be made to the structures described above without falling outside the scope of the claims attached. In particular, the feed-lines can be realised using techniques other than the coplanar technology or coaxial cables, the outer core of which is connected to the substrate.